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CYCLONE-ELECTROTHERMAL METHODS OF PROCESSING COPPER AND POLYMETALLIC MATERIALS: EFFECT OF SOME FACTORS ON REMOVAL OF MATERIAL BY GASES IN CYCLONE SMELTING

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CYCLONE-ELECTROTHERMAL METHODS OF PROCESSING COPPER AND POLYMETALLIC MATERIALS

[Tsiklonno-elektrotermicheskiye sposoby pererabotki mednogo i polimetallicheskogo syr'ya]

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This volume contains articles summarizing the results of investigations of processing the copper and polymetallic concentrates and other products of nonferrous metallurgy by the cyclone method. The results of theoretical studies of the technology of cyclone smelting of sulfide concentrates are also included. Certain structural features of a cyclone facility for direct-flow and separated outflow of the smelting products and of gas are described. Also, technological characteristics are given for smelting of copper concentrates of Central Kazakhstan, industrial concentration products of the lead-zinc ores, and oxidized materials.

The material in this volume will be of interest to scientists, workers in metallurgical plants who investigate methods of processing sulfide concentrates in pulverized form, and to instructors and students in the institutions of higher learning.

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EFFECT OF SOME FACTORS ON REMOVAL OF MATERIAL BY GASES IN CYCLONE SMELTING

V.D. Budon

The behavior of a solid suspension in composite spatial gas streams has been studied quite insufficiently, and even then only as applicable to isothermal streams and nonflammable particles [1]. No theory of curvilinear motion of material particles in a cyclone chamber has been really developed, and the problems of material losses in the form of dust are being solved either by empirical means or by analogy to the processes of fuel burning in powered cyclones.

This paper makes an attempt to reveal factors which determine the removal of dust by gases in cyclone smelting. The material is based on special studies, performed by us and other authors on the cold and hot models of cyclone chambers, and on results obtained on consolidated-laboratory and semi-industrial facilities during the smelting of various copper and polymetallic concentrates.

The laboratory investigations [2] of an isothermal dust-containing gas stream of various models of cyclone chambers have shown that the presence of solid particles in the gas current exerts a pronounced effect on its total aerodynamic characteristics (the velocity field and pressure in the current), but the structure of the stream remains basically unchanged.

An essential difference between the dust-carrying stream and the pure one is a lower level of rotational velocities of the former, at

the same throughput of air and the same geometry of the chamber. With a decrease of the twist in the cyclone, there is a corresponding decrease of static pressure at its periphery, as well as a decrease of the size of the central vortex and the input resistance coefficient. This is determined by the fact that a part of the current energy is expended on transport of the solid phase. As a result, the coefficient of retention of the current velocity (E) has a lower value than in the pure current.

The physical nature of the coefficient E consists of a lowering of the general level of velocities at the outlet, because of a broadening of the narrow air stream flowing out of the outlet nozzles into the cyclone, and rearrangement of its velocity field according to the rotating current law:

$$E\varepsilon = \frac{Wt_{cp}}{W_{in}},$$

Where Wt_{cp} — rotational velocity of the cyclone current, taken at a radius equal to the average input radius, m/sec;

W_{in} — velocity of the gas input into the cyclone, m/sec.

At small relative inlet areas ($\frac{\Sigma f_{in}}{F_c} \cdot 100 = 10\%$), the lowering of the stream velocity becomes quite noticeable, particularly in dust-carrying streams. Figure 1 shows the reduction of the coefficient E as a function of the amount of solid material suspended in the stream (K_{cp}):

$$K_{cp} = \frac{B}{Q_{in}} \gamma 0,$$

where B — throughput of solid body, kg/hour;

Q_{in} — throughput of air, m^3/hour.

Regarding the suspension distribution in a cyclone chamber, and also the effect of fractional composition and charge specific weight on the gas removal, we can say that only the qualitative side of these phenomena has been studied. In experiments performed on cold and hot models of the cyclone chambers of the type "A" (Figure 2), with tangential delivery of the fuel and air, the overwhelming

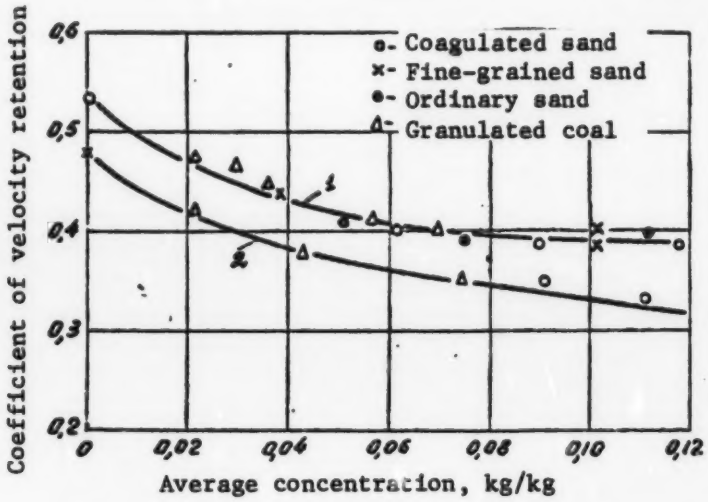

Figure 1. The coefficient of velocity retention E in a dust-containing stream.

1. $\frac{dc}{D_c} = 0.4$ 2. $\frac{dc}{D_c} = 0.5$

majority of solid particles introduced into the cyclone were in a relatively narrow region adjacent to the walls. Out of the total mass of particles introduced into the chamber, only a small portion of particles with dimensions less than 10 microns were detached and moved towards the center. At the same time, a considerable amount of such fine particles remained in the mass of the material along the top of the chamber in layers close to the periphery. The width (along the radius) of a dust ring rotating at the wall varies, depending on the fractional composition of the material.

The most dense and adhering to the wall were rings of particles 0.07-1.0 mm in size. This movement of the particles of a dense mass along the periphery of the chamber creates the conditions of "obstruction" at relatively small average concentrations, for instance at 0.055-0.06 kg/kg for sand 0.1 mm in size (70%). With an increase of the size of grains of the solid phase, the value of "critical" concentrations increases. For instance, at W_{in} = 50 m/sec, the value of K_{cp} was 0.09-0.1 kg/kg for granulated coal having 70% particles of the 0.8 mm size, and the value of K_{cp} changed to 0.15-0.16 kg/kg for sand with 70% with 0.3 mm grains.

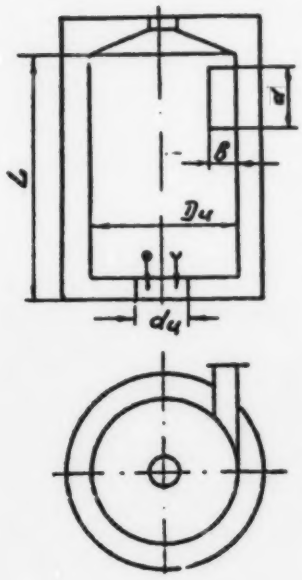

Figure 2. Cyclone chamber of the type "A". D_c — diameter of cyclone; dc — diameter of diaphragm; L — length of cyclone; a — height of slit; b — width of slit.

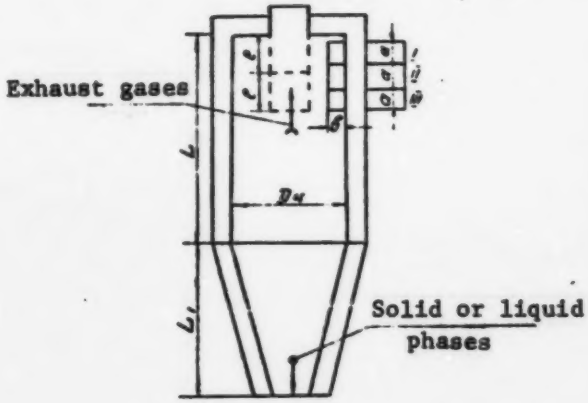

Figure 3. Cyclone chamber of the type "B". I, II and III — inlets for secondary air.

The coagulation of the solid phase changed the particle motion. Trajectories of separate particles represented a system of closed broken lines passing around the chamber, as a result of collisions of particles against the walls of the chamber. These particles (2-5 mm in size) entered the zone of the exhaust whirl and were carried away by it from the cyclone chamber.

Naturally, the loss of dust from the chamber should become greater under conditions leading to the formation of local overloading of the current. As a result, particles of material fall out of the stream earlier, before they can reach the wall of the chamber. This phenomenon is possible at: a) a disturbance of the aerodynamics of dust-containing gaseous current as a result of either low or very high W_{in} and a small coefficient E; b) an excessively high average weight concentration of the solid material in the stream — K_{cp}; and c) unfavorable fractional composition of the material, usually the presence in it of a considerable amount of particles less than 10 microns in size, or larger than 2 mm.

Investigation of the dust transport on cold models of cyclone chambers of the "B" type (Figure 3), and during the operation of experimental facilities using various ores, has shown that the amount of dust lost in both types of the chambers, "A" and "B", is determined by the same factors which were just considered. However, the loss of dust from chambers of the "B" type is somewhat smaller than that from chambers of the "A" type. This fact is connected with the separate outlets for the liquid (or solid) phase and the gas phase provided in chambers of the "B" type.

During the calcination of ilmenite concentrates in a cyclone chamber of the "B" type, the maximum dust loss of cinders amounted to 8% of the weight of initial material. From the data on the granulometric composition of the initial concentrate, the cinders obtained, and the dust (Figure 4), we find that particles with diameter less than 80 microns are preferentially carried away from the cyclone chamber.

Also, when investigating the dependence of the fractional composition of captured dust (cinders) on the fractional composition of initial concentrate and the obtained cinders and dust (Figure 4), we find that particles of diameter less than 80 microns are mostly removed from the cyclone chamber.

The loss of particles more than 100 microns in size is small, and less dependent on the operational conditions of the chamber. Thus, the loss is 5 weight % of the initial fraction with diameter of 150 microns, and is 2-3% for particles with a diameter of 220 microns.

The results of investigating the effect of the location and velocity of input (W_{in}) of air and the charge, and also the location of the central tube, on the amount of dust loss of the 0.1-0.5 mm fraction in Dzhezkazgansk concentrate from a chamber of "B" type (Figure 3), have shown that this depends to a considerable degree on the gas input velocity W_{in}, and to a lesser degree on other factors.

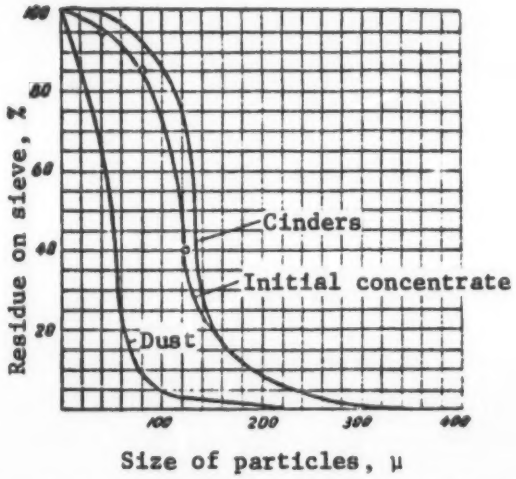

Figure 4. Granulometric composition of cinders, dust, and initial concentrate.

Figure 5 shows the dependence of dust loss on the above-mentioned factors.

As seen from the graph, beginning with the velocity W_{in} = 65 m/sec the loss of dust from the chamber increases, irrespective of the site of introduction of secondary air. This behavior is particularly noticeable under conditions when the central gas-outlet tube is not immersed in the cyclone chamber. For instance, when W_{in} at the second air input changes from 30 to 65 m/sec, the loss of dust remains practically the same and amounts to 5% of the weight of material charged into the chamber. An increase of the air input velocity to W_{in} = 100 m/sec leads to an increase of the dust loss to 22.5%. As is known, an analogous behavior is observed in the case of dust-removing cyclones, where — after exceeding a certain level of the velocity of the gas stream — the efficiency of the cyclone sharply falls. This phenomenon is explained by the appearence of whirls which remove the particles of dust already deposited or located near the wall of the chambers, followed by these particles being carried away by the central gas current. In comparison with the effect of W_{in}, the influence of the site of introducing secondary air into the chamber is slight, and is noticeable only under conditions when the outflow of gas from the chamber

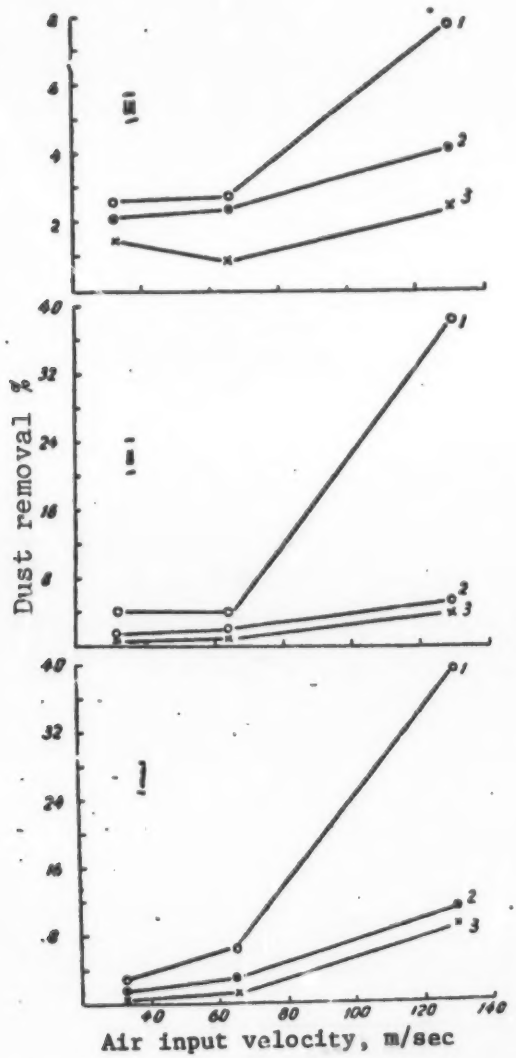

Figure 5. Dust removal as a function of the input velocity of the secondary air, under conditions: 1 - without the central tube; 2 - central tube immersed in the cyclone at the length l; 3 - central tube immersed in the cyclone at $2l$; I, II and III - location of input of the secondary air.

takes place without the central tube. All the above-considered results of studies of the dust losses were obtained where the cyclone chamber was utilized for technological processes not connected with smelting of materials.

In recent years, considerable interest has developed in a number of branches of industry with regard to technological processes of the conversion of materials, with their smelting in cyclone chambers of the type "A" or "B".

The melting of material and formation of a liquid layer of melt on the walls of the cyclone chamber should have a beneficial effect on the decrease of the loss of material from the cyclone, in comparison with the loss incurred under the conditions of the solid-phase system. The analysis of the results of facilities smelting various materials shows that the mechanical loss of these materials amounts to 4.5-10% in this case. This is somewhat more than in the solid-phase system. This increased mechanical loss of material should be explained by the operation of chambers with higher specific charges (K_{cp} 0.1-0.3 kg/kg) and at higher W_{in} (100-150 m/sec), required for maintaining the cyclone effect.

A noticeable increase of the mechanical loss of material occurs with an increase (more than 8-19 m/sec) of the exit velocity of a gas leaving the cyclone chamber. In smelting chambers the blockage of gas outlet openings with the melt will lead, as a rule, to an increase of such a velocity.

As far as the high-melting charges (melting point t_m 1300°) are concerned, the effect of fractional composition on the mechanical loss of material is nearly the same as in the case of cyclone chambers without melting the material. For instance, in an attempt to process rich zinc-containing powder with a particle size less than 10 microns by the cyclone method, the mechanical loss of the initial material amounted to more than 60%. Apparently, the processing in cyclones of metallurgical flotation concentrates whose particle size, as a rule, is less than 74 microns would be impossible because of high dust losses if their main mass did not consist of low-melting minerals.

To reduce the melting temperature of concentrates containing minerals without metals, "fluxes" are usually added to them. The softening, conglomeration and melting of fine particles of the charge, forming large droplets and a liquid mobile layer of melt on the walls of the smelting chamber, prevent the removal of material, and make the operating conditions of a smelting chamber similar to the operating of dust-removing wet cyclones. Table 1 shows the degree of conversion of waste rock components into dust in the cyclone smelting of a charge of Dzhezkazgansk copper concentrate. The composition of charge in % was: copper 33-36, lead 2-3, zinc 1.5-2, silica 22-24, iron 7-8, calcium oxide 1.5-2, alumina 4-2.5, magnesium oxide 0.5, and ground limestone (flux) — up to 20.

It is necessary to note that results close to those listed in the Table were also obtained during smelting of Balkhash ores [8].

Although the mechanical loss of material is 3-7%, the total yield of dusts varies within broad limits and depends on the chemical composition of the processed raw material. Cyclone smelting is a

TABLE 1.

Smelting of copper concentrate	Yield of components, in % of their initial content in the charge				
	SiO_2	CaO	FeO	Al_2O_3	MgO
Blister copper	1.43	3.90	12.70	6.34	10.96
matte	1.96	5.15	11.98	3.72	12.39

high temperature process, providing good conditions (the developed surface of reacting phases, with a total large volume of the gas phase) for sublimation of the volatile components of the charge and products of reaction. Hence lead, zinc, cadmium, and other metals and their compounds, to a large extent pass into the gas phase and, in the form of finely-dispersed dust, are carried away from the cyclone chamber. The specific feature of such chambers — the failure to capture particles less than 10 microns in size — makes it possible to concentrate volatile components of the processed concentrates in the cyclone dusts.

As is seen from data in Table 2, during the cyclone smelting of polymetallic materials there is a considerable amount of total dust produced (16-32.6%), in which lead, zinc and other metals become concentrated. According to data in [5, 8], these dusts contain also a considerable concentration of such elements as cadmium, thallium, rhenium, and others.

The importance of dusts of cyclone smelting requires that the facilities be equipped with a system for dust capture, ensuring high efficiency in the case of finely dispersed powdery materials.

Conclusions

1. Factors which determine the removal of dust in dust-removal cyclones are basically the same as those which determine the mechanical loss of material from the smelting chambers.

TABLE 2.

Processed material	Yield of dust, % of weight of material	Copper		Lead		Zinc	
		Content in dust, %	Yield, % of initial content	Content in dust, %	Yield, % of initial content	Content in dust, %	Yield, % of initial content
Zinc cakes	32.60	0.53	7.1	14.80	91.50	53.00	87.40
Achisaysk oxidized ore	19.33	—	—	5.77	78.63	48.73	79.42
Nikolayev oxidized ore	31.63	2.50	4.0	12.00	88.00	40.00	61.40
Collective concentrate	16-20	2-3	5.0	6-10	75-85	28-26	62-65

2. The mechanical loss of material from smelting cyclones does not exceed the loss in the existing pyrometallurgical units and amounts to 3-5% of the processed batch weight.

3. During processing of polymetallic ores, the total yield of dust depends on the content of volatile elements and can exceed 30% of the charge weight.

4. Finely-dispersed and high-melting dusts of cyclone smelting cannot return in the cyclone process.

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